IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

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Inventor:	David E. Albrecht
Title:	FLANGE PLATES FOR FLUID PORT INTERFACES
Examiner:	Alison K. Pickard
Art Unit:	3676
File No.:	505-02

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DECLARATION OF DAVID E. ALBRECHT UNDER RULE 132

David E. Albrecht declares as follows:

1. I am the applicant in the above-identified application. I have reviewed the Official Action of September 11, 2002, and I make this Declaration in partial response thereto.

2. The Examiner has argued, in effect, that the patents to Smith and Stone come from analogous arts, and that it would be obvious, to a person of ordinary skill, to combine their teachings.

3. I have worked for many years in the field of fluid handling devices. From my experience in this field, I know that threaded seals, as represented by Stone, and annular seals, as represented by Smith, are considered substantially different in the art. Threaded seals represent old art, and are not considered suitable for high pressure fluid handling applications. I believe that a person of ordinary skill would not look to the old and discredited art of threaded sealing, for guidance in fabricating a modern high-pressure seal.

4. The fluid handling literature demonstrates the difference between threaded sealing and annular (O-ring) sealing, and shows that O-ring seals are considered far superior. The following paragraphs of this Declaration describe various citations to this literature.

5. The article from Hydaulics & Pneumatics Magazine, May, 1997, entitled "Zero-leak hydraulics: reality or fantasy?" contains a clear statement about the attitude of persons skilled in the art, concerning threaded pipe seals:

> Incidentally, it should go without saying that there is no place in world-class hydraulic circuits for tapered threads. Using pipe threads in a modern hydraulic system would be like trying to build a modern computer with a 286 or older processor. It may be a cheap answer initially, but the continual poor performance will make you regret your short-sighted decision over and over until you inevitable [sic] retrofit the system with O-ring style fittings.
>
> *　*　*　*
>
> The consensus of opinion is that an elastomeric seal versus metal-to-metal sealing provides the best overall zero-leak performance.

6. The article entitled "Fittings", in the 1998/1999 Fluid Power Handbook & Directory, characterizes all-metal threaded fittings as "obsolete". The article explains as follows:

> Pipe threads are prone to leakage because they are torque-sensitive--over-tightening distorts the threads and creates a path for leakage around the threads. Moreover, pipe threads are prone to loosening when exposed to vibration and wide temperature variations--certainly no strangers to hydraulic systems.
>
> Seapage around threads should be expected when pipe fittings are used in high-pressure hydraulic systems. ... Thread sealant compound is recommended for pipe fittings, which is still another reason why most designers consider them to be obsolete for use in hydraulic systems.

This reference then describes various modern fittings, all of which rely on an elastomeric seal, such as an O-ring. Note that, although the modern fittings have threads, the threaded connections are used only for the mechanical joining of components, not for creating a fluid seal itself.

7. The Fluid Power Design Handbook, First Edition, 1996, page 64, describes threaded and non-threaded connectors. The reference states that the threaded connection is "not recommended" by the National Fluid Power Association. On the other hand, the straight thread O-ring connection is recommended for optimum leakage control in medium and high pressure hydraulic systems. The references adds that the threads in the latter connector hold the connection mechanically, but that the fluid seal is produced by the O-ring.

8. The attached references fairly summarize the state of the art at the time the present invention was made. These references clearly show that, for medium and high pressure fluid handling applications, threaded seals are strongly disfavored. To obtain essentially leakproof performance, it is necessary to use an elastomeric (O-ring) seal.

9. Therefore, a person of ordinary skill in the art of fluid handling components, when seeking to improve a seal for use in a medium or high pressure application, would not think of consulting a reference which deals with threaded seals. Threaded seals are essentially obsolete.

10. I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

Date: 1-10-03

David E. Albrecht

Zero-leak hydraulics: reality or fantasy?

(continued from previous page)

H&P What makes you so sure that those days are gone, and what is a "savvy user"?

Swisher: World-class hydraulic users know that zero-leak components and systems are a given from this time forward. These savvy users are well aware of the many advantages of zero-leak systems. They also know that the cost of not insisting on zero-leak performance shows up in disposal costs, service calls, and dissatisfied or lost customers.

H&P: What techniques do these savvy users employ to achieve zero-leak performance?

Swisher: Early on I was asked to define zero leakage in order to have a measurable benchmark. To focus on the issues of achieving zero leakage instead of semantics or words, I stated: "Zero leakage means less than one drop in five days with no visible oil present at any interface during first inspection." In our world-class machines, we expect continuous improvement and will find it necessary to refine this definition even further.

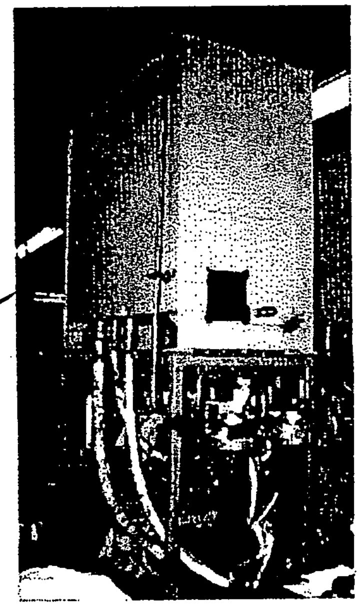
Zero-leak performance occurs when all elements of the hydraulic systems

Equally important to eliminating the fitting variations by standardizing on an O-ring type design is to properly apply them, specifically in terms of proper torque. The savvy world-class user marks every fitting and sealing component bolt with a die indication that it has, indeed, been torqued to specification.

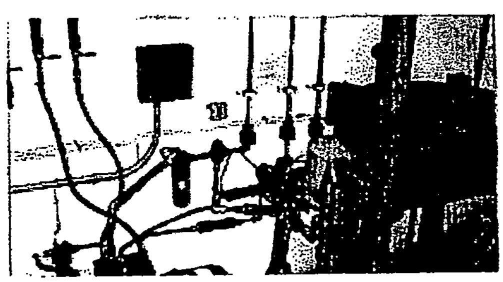
Incidentally, it should go without saying that there is no place in world-class hydraulic circuits for tapered threads. Using pipe threads in a modern hydraulic system would be like trying to build a modern computer with a 286 or older processor. It may be a cheap answer initially, but the continual poor performance will make you regret your short –sighted decision over and over until you inevitable retrofit the system with O-ring style fittings.

H&P: What do you see the hydraulic system of the future to be?

Swisher: Our company's retired vice president of technology, Jim Bloomquist, described the hydraulics of the future well by drawing the comparison to refrigerators and air conditioning systems. First, the hydraulic fluid will be in a sealed reservoir and invisible to the machine user. The reservoir will be very small compared to those sized



A reservoir of traditional size, such as the one pictured here, holds five to six times the flow delivered by the pump in 1 min and will not be part of the leak-free hydraulic system of the future. Instead, reservoirs will be sized about [illegible] the flow delivered by the pump in 1 min.



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are designed, installed and maintained behind a zero-leak attitude. Let's talk about some prime examples. First, design machine operations to minimize shock. As you might imagine, shock and vibration can cause fittings to loosen or in some cases, fail. With today's technology, there is no reason to accept harsh hydraulic control. Programmable velocity and acceleration ramps via electrohydraulic valves in open-or closed-loop control are readily available. Even something as simple as applying soft-shift directional valves can make a significant contribution toward reducing shock.

H&P: Wouldn't this reduce shock in the hydraulics benefit the basic mechanical integrity of the machine as well?

Swisher: Absolutely. Incidentally, some of the things done to reduce sound levels of machines also promote zero-leak integrity. Pulsation dampers in pump outlets, vibration suppressing clamps for rigid tubing, and the strategic use of hose to minimize pumping pressure pulsations all work to absorb vibration and shock. The result is a quieter, longer lasting, zero-leak machine.

H&P: Please continue; what are some other techniques?

Swisher: Printed circuits for hydraulics, often called hydraulic integrated circuits, dramatically enhance the progress toward zero-leak performance. These are compact circuits with no external plumbing between control valves because valves are contained within an aluminum or steel manifold block. Reducing the number of dynamic seals in favor of static seals can also be a real plus. Using submerged, in-tank pumps or integrated pump-motor packages eliminates the threat of pump shaft leakage.

by the traditional rule of thumb. For stationary applications, instead of sizing reservoirs at 5 to 6 times the pump output flow in 1 minute, they will be about 1/10 the pump delivery per minute instead of *equal to* the pump flow output in 1 minute.

H&P: Now wait a second! The reservoir traditionally has been used as a heat dissipater, contamination settler, and air removal device. How do you accomplish these functions with such a small reservoir?

Swisher: Aeronautic applications of hydraulics have correctly earmarked the reservoir's role in the circuit by calling it a volume *compensator*. Its sole function is to allow for changes in circuit fluid volume due to actuators extending and retracting and volume variations due to temperature changes. This will be the only role a reservoir-of-the-future plays.

Heat removal in the circuits of the future will be via heat exchangers of various types. It will no longer be appropriate to accomplish this through sheer volume of fluid residing in a tank. Contamination removal will be done by good filtration systems typically designed in as a low pressure kidney loop for heat and contamination removal.

Air removal is also key. A lesson from automotive brake systems and air conditioning systems serves well here! Air in a newly built hydraulic circuit will be evacuated before hydraulic fluid is added. The sealed reservoir system will not have an air/oil interface but rather a bladder interface. A small, positive, bias pressure will be present and monitored by sensors to notify the machine controller of any fluid volume loss.

H&P: So in summary, then, it sounds like zero-leak performance requires a commitment from not

Prototype of hydraulic system of the future uses small, sealed reservoir, submerged pump, soft-shift directional and proportional valves, and ISO standard fittings having elastomeric sealing interfaces.

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H&P: What about the choice of fittings? The industry offers a large variety.

Swisher: Yes indeed. But some leaks result from that large variety! Larger plants are commonly faced with a number of different manufacturers' machines with a need to stock various fitting styles to service them. The inevitable mixing of two different but connectable fittings guarantees a leak.

H&P: So what fittings do you recommend for a zero-leak system?

Swisher: Choose hydraulic fittings that use elastomeric sealing and select the best ISO standards. Use elastomeric seals at every interface-specifically ISO 6149 straight thread, O-ring ports, ISO 8434-3 O-ring face steal fittings, and ISO 6162.2 four-bolt, O-ring flange connections. The consensus of opinion is that an elastomeric seal versus metal-to-metal sealing provides the best overall zero-leak performance.

only the machine builder, but users and component suppliers as well.

Swisher: Absolutely. None of the participants can achieve zero-leak performance single-handedly. It is also not possible to pick one element and expect a cure-all for the entire circuit. By this I mean, the thinking, "Well, I will change all my seal material from nitrile to fluorocarbon and stop my leaks," will not do it!

A final element, equally important, is awareness-awareness that hydraulic systems don't have to leak and an awareness of how to successfully apply these techniques to achieve zero leakage. It's not an easy goal to attain, but zero-leak hydraulics is definitely a reality!

May 1997/Hydraulics & Pneumatics

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Fittings

Among the basic elements of virtually every hydraulic system is a series of fittings for connecting tube, pipe, and hose to pumps, valves, actuators, and other components.

If components within the hydraulic system never had to be removed, connections could be brazed or welded to maximize reliability. However, it is inevitable that connections must be broken to allow servicing or replacing components, so removable fittings are a necessity for all but the most specialized hydraulic systems. To this end, fitting designs have advanced considerably over the years to improve performance and installation convenience, but the overall function of these components remains relatively unchanged.

Fittings seal fluid within the hydraulic system by one of two techniques: all-metal fittings rely on metal-to-metal contact, while O-ring type fittings contain pressurized fluid by compressing an elastomeric seal. In either case, tightening threads between mating halves of the fitting (or fitting and component port) forces two mating surfaces together to form a high-pressure seal.

All-metal fittings

Threads on pipe fittings are tapered and rely on the stress generated by forcing the tapered threads of the male half of the fitting into the female half or component port, Figure 1. ~~Pipe threads are prone to leakage because they are torque-sensitive — over-tightening distorts the threads and creates a path for leakage around the threads.~~ Moreover, pipe threads are prone to loosening when exposed to vibration and wide temperature variations — certainly no strangers to hydraulic systems.

~~Seepage around threads should be expected when pipe fittings are used in high-pressure hydraulic systems.~~ Because pipe threads are tapered, repeated assembly and disassembly only aggravates the leakage problem by distorting threads, especially if a forged fitting is used in a cast-iron port. Thread sealant compound is recommended for pipe fittings, which is still another reason why most designers consider them to be obsolete for use in hydraulic systems.

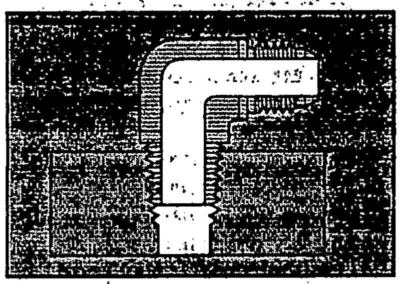

Fig. 1. Pipe fittings have given way to newer fitting designs that simplify assembly, maintenance, and reduce or eliminate leakage. Shown is a 90° adapter elbow with pipe threads at one end that mount permanently into the component port. Other end of fitting uses straight-thread flare fitting for tubing connection.

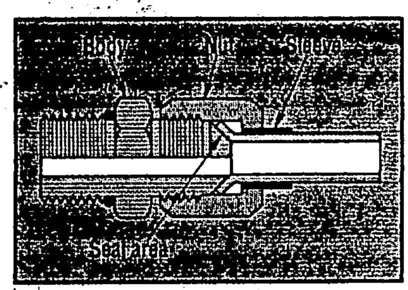

Fig. 2. Flare-type fittings offer several design and performance improvements over pipe fittings and are used with thin-walled and medium-thickness tubing.

Flare-type fittings, Figure 2, were developed as an improvement over pipe fittings many years ago and probably remain the design used most often in hydraulic systems. Tightening the assembly's nut draws the fitting into the flared end of the tubing, resulting in a positive seal between the flared tube face and the fitting body. The 37° flare fittings are designed for use with thin-wall to medium-thickness tubing in systems with operating pressures to 3000 psi. Because thick-wall tubing is difficult to deform to produce the flare, it is not recommended for use with flare fittings. The 37° flare fitting is suitable for hydraulic systems operating at temperatures from – 65° to 400°F. It is more compact than most other fittings and can easily be adapted to metric tubing. It is readily available and one of the most economical.

The flareless fitting, Figure 3, gradually is gaining wider acceptance in the U.S. because it requires minimal tube preparation. It handles average fluid working pressures to 3000 psi and is more tolerant of vibration than other types of all-metal fittings. Tightening the fitting's nut onto the body draws a ferrule into the body. This compresses the ferrule around the tube, causing the ferrule to contact, then penetrate the outer circumference of the tube, creating a positive seal. Because of this, flareless fittings must be used with medium- or thick-walled tubing.

O-ring type fittings

~~Surprising as it may seem, leakage in hydraulic systems was licked more than a generation ago — or should have been.~~ Although leak-free hydraulic operation has always been desirable, the need became more acute with higher operating pressures that became necessary during World War II, primarily in the hydraulic systems of military aircraft. Until then, common operating pressures had hovered around 800 to 1000 psi. The post-war era ushered in systems designed to operate at pressures to 1500 psi and higher on applications where rapid cycling and high shock pressures were common. It was not long until pressures climbed to 2500 and 3000 psi — which certainly are not uncommon today.

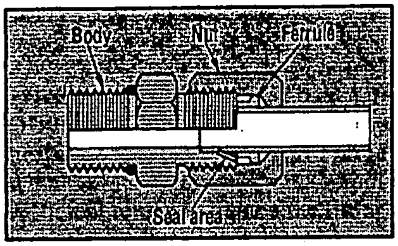

Fig. 3. Flareless fittings offer advantages similar to those of flare fittings and are used with medium- to thick-walled tubing.

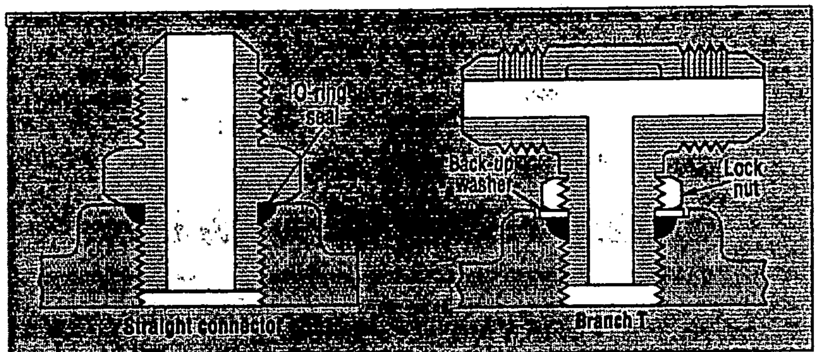

Fig. 4. Non-adjustable, left, and adjustable SAE straight-thread O-ring fittings offer ease of assembly and high potential for leak-tight connections.

Faced with increased hydraulic fluid leakage brought on by higher pressures, a consortium of fittings manufacturers — working under the umbrella of SAE's Committee on Tubing, Piping, Hoses, Lubrication, and Fittings — undertook solving the problem of hydraulic leakage. Their joint effort in the early 1950s culminated in the straight-thread design, which ultimately became known as the SAE straight-thread O-ring boss.

Fittings that use O-rings for leak-tight connections continue to gain acceptance by equipment designers around the world. Three basic types now are available: SAE straight-thread O-ring boss (also known as straight-thread port) fittings, face seal or flat-face O-ring (FFOR) fittings, and O-ring flange fittings. The choice between O-ring boss and FFOR fittings usually depends on such factors as fitting location, wrench clearance, or individual preference. Flange connections generally are used for applications requiring tubing with an OD greater than 7/8-in. or those involving extremely high pressures.

O-ring boss fittings seat an O-ring between threads and wrench flats around the OD of the male half of the connector, Figure 4. A leak-tight seal is formed against a machined seat on the female port. O-ring boss fittings fall into two general groups: adjustable and non-adjustable. Non-adjustable (or non-orientable) fittings include plugs and connectors. These are simply screwed into a port, and no alignment is needed. Adjustable fittings, such as elbows and tees, need to be oriented in a specific direction.

The basic design difference between the two types is that plugs and connectors have no locknuts and require no back-up washer to effectively seal a joint. They depend on their flanged annular area to push the O-ring into the port's tapered seal cavity and squeeze the O-ring to seal the connection. Adjustable fittings are screwed into the mating member, oriented in the required direction, and locked in place and when a locknut is tightened. Tightening the locknut also forces a captive backup washer onto the O-ring, which forms the leak-tight seal. Assembly is always predictable, because technicians need only make sure that the backup washer is firmly seated on the port's spot face surface when the assembly is completed and that it is tightened properly.

The FFOR fitting forms a seal between a flat, finished surface on the female half and an O-ring held in a recessed circular groove in the male half, Figure 5. Turning a captive threaded nut on the female half draws the two halves together and compresses the O-ring.

Fittings with O-ring seals offer a number of advantages over metal-to-metal fittings. While under- or over-tightening any fitting allows leakage, all-metal fittings are more susceptible to leakage because they must be tightened to within a higher, yet narrower torque range. This makes it easier to strip threads or crack or distort fitting components, which prevents proper sealing. The rubber-to-metal seal in O-ring fittings does not distort any metal parts and provides a tangible "feel" when the connection is tight. All-metal fittings tighten more gradually, so technicians may have trouble detecting when a connection is tight enough but not too tight.

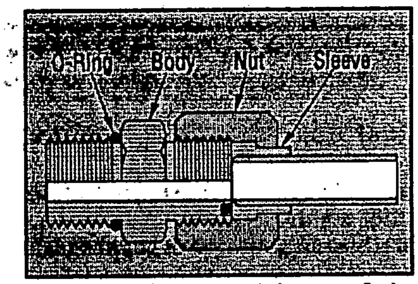

Fig. 5. Flat-face O-ring fitting uses O-ring in recessed groove in male half that mates with flat, smooth surface on female half.

On the other hand, O-ring fittings are more expensive than their all-metal counterparts, and care must be exercised during installation to ensure that the O-ring doesn't fall out or get damaged when the assemblies are connected. In addition, O-rings are not interchangeable with all couplings. Selecting the wrong O-ring or reusing one that has been deformed or damaged can invite leakage. Once an O-ring has been used in a fitting, it is not reusable, even though it may appear free of distortions.

Some manufacturers offer specially designed, high-pressure fittings that are equal in leak and weep resistance to FFOR fittings and interchangeable with a number of international fittings. Testing has shown these new designs to surpass all requirements with no evidence of leakage when exposed to vibrations up to 15 times more severe than those experienced on a typical hydrostatic drive. These designs may appear similar to standard fittings, but should not be mated with fittings from different manufacturers.

Hydraulic flanges

Fittings for tubing larger than 1-in. OD have to be tightened with large hexes which, in turn, require larger wrenches to enable workers to apply sufficient torque to tighten the fittings properly. To install such large fittings, system designers must provide the necessary space to give workers enough room to swing these large wrenches. Extensions would likely be needed for some workers to exert an applicable amount of torque. In addition, worker fatigue and strength must be considered.

Fittings manufacturers have designed split-flange fittings so that they overcome both of these problems. Split-flange fittings, Figure 6, use an O-ring to seal a joint and contain pressurized fluid. An elastomeric O-ring rests in a groove on a flange and mates with a flat surface on a port — an arrangement similar to the FFOR fitting. The O-ring flange is attached to the port using four mounting bolts that tighten down onto flange clamps, thus eliminating the need for a large wrench when connecting large-diameter components. When installing flange connections, it is important to apply even torque on the four flange bolts to avoid creating a gap through which the O-ring can extrude under high pressure.

The basic split-flange fitting consists of four elements: a flanged head connected permanently (generally welded or brazed) to the tube, an O-ring that fits into a groove machined into the end face of the flange, and two mating clamp halves with appropriate bolts to connect the split-flange assembly to a mating surface.

All mating surfaces must be clean and smooth. Where perpendicular relationships are critical, all parts must meet appropriate tolerances. While 64-µin. surface finishes are acceptable, most flange manufacturers prefer and recommend 32-µin. finishes on mating surfaces to ensure leak-free connections. Joints are more likely to leak if either of the mating surfaces are scratched, scored, or gouged. Additionally, wear tends to accelerate on O-rings which are assembled against rough surfaces.

In a properly designed split flange assembly, the flange shoulder protrudes approximately 0.010 to 0.030 in. beyond the clamp face to ensure adequate contact and seal squeeze with the mating face, Figure 6. However, the clamp halves *do not* actually contact the mating surface. The most critical phase of assembling a split-flange fitting to its mating surface is to make certain that the four fastening bolts are tightened gradually and evenly in a cross pattern. Air wrenches should not be used because they are difficult to control and can easily over-tighten a bolt.

Fully tightening one of the bolts while the others are still loose will tend to cause the flange to tip upward, Figure 8. This action pinches the O-ring, and the joint can then be expected to leak. When the bolts are fully tightened, the flanges sometimes bend downward until they bottom on the port face, and the bolts bend outward, Figure 8. Should flanges and bolts bend, they tend to lift the flange off the shoulder; once again, the result will be a leaking joint.

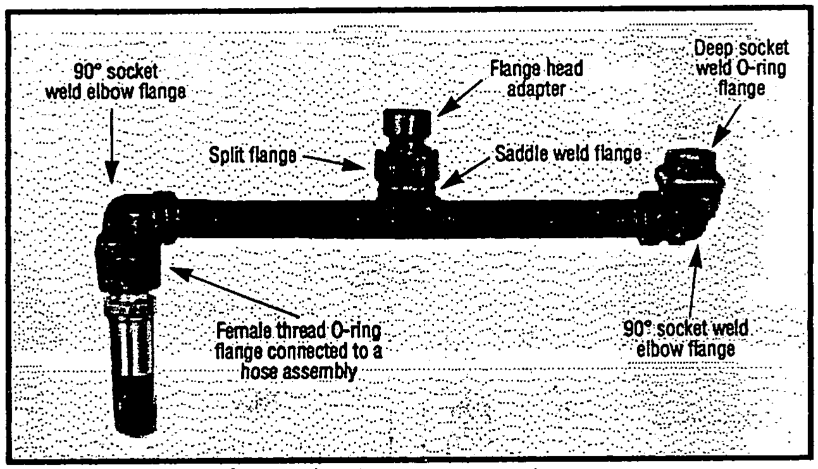

Fig. 7. Weld-type fittings used in conjunction with SAE 4-bolt flange clamp halves and O-ring flange head couplings offer convenience, economy for hydraulic connection assemblies.

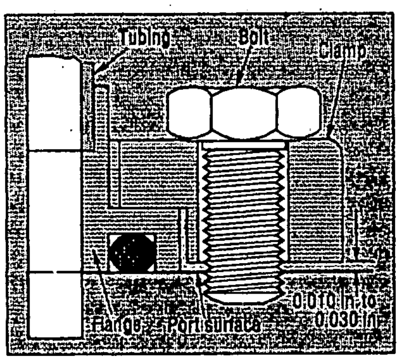

Fig 6. Properly designed and installed split-flange fitting has a uniform clearance of 0.010 to 0.030 in. between the port surface and clamp halves.

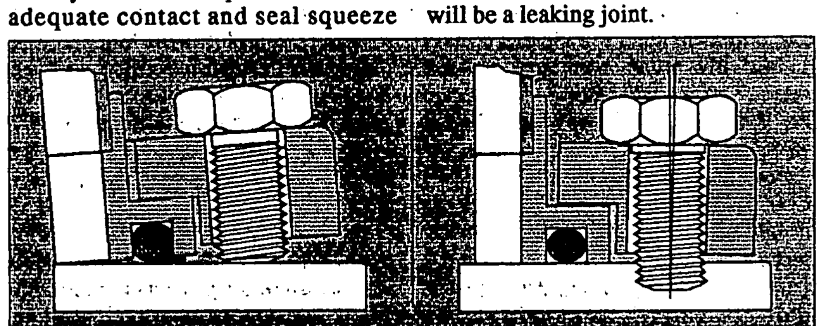

Fig. 8. Unevenly tightened split-flange bolts may cause flange to tip up and damage O-ring, as shown at left, while over-tightened bolts, right, can bend the flange and bolts.

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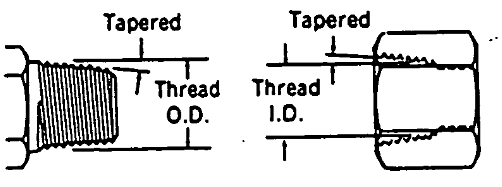
American Connections

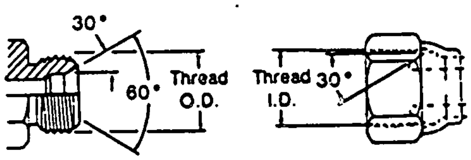
NPTF
National Pipe Tapered Fuel



Male Half | Female Half

This connection is still widely used in fluid power systems, even though it is not recommended by the National Fluid Power Association (NFPA) for use in hydraulic applications. The thread is tapered and the seal takes place by deformation of the threads.

NPSM
National Pipe Straight Mechanical



Male Half | Female Half

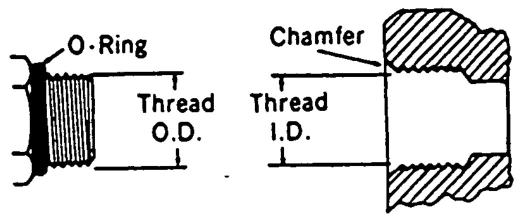
This connection is sometimes used in fluid power systems. The female half has a straight thread and an inverted 30° seat. The male half of the connection has a straight thread and a 30° internal chamfer. The seal takes place by compression of the 30° seat on the chamfer. The threads holds the connection mechanically.

NOTE: A properly chamfered NPTF male will also seal with the NPSM female.

Inch Size	Dash Size	Nominal Thread Size	Male O.D. (Inch) Fraction	Male O.D. (Inch) Decimal	Female I.D. (Inch) Fraction	Female I.D. (Inch) Decimal
1/8	02	1/8-27	13/32	.41	3/8	.38
1/4	04	1/4-18	17/32	.54	1/2	.49
3/8	06	3/8-18	11/16	.68	5/8	.63
1/2	08	1/2-14	27/32	.84	25/32	.77
3/4	12	3/4-14	1 1/16	1.05	1	.98
1	16	1-11 1/2	1 5/16	1.32	1 1/4	1.24
1 1/4	20	1 1/4-11 1/2	1 21/32	1.66	1 19/32	1.58
1 1/2	24	1 1/2-11 1/2	1 29/32	1.90	1 13/16	1.82
2	32	2-11 1/2	2 3/8	2.38	2 5/16	2.30

NOTE: For NPTF threads, measure thread diameter and subtract 1/4-inch to find the nominal pipe size.

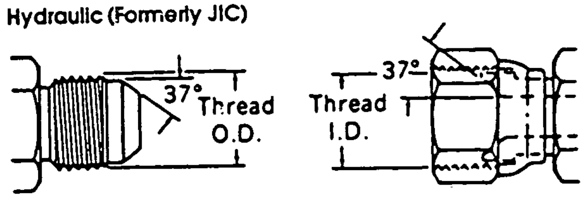
SAE J514 Straight Thread
O-Ring Boss (ORB)



Male Half | Female Half

This port connection is recommended by the NFPA for optimum leakage control in medium and high pressure hydraulic systems. The male connector has a straight thread and an o-ring. The female port has a straight thread, a machined surface (minimum spotface) and a chamfer to accept the o-ring. The seal takes place by compressing the o-ring into the chamfer. The threads hold the connection mechanically.

SAE J514 37°
Hydraulic (Formerly JIC)



Male Half | Female Half

This connection is very common in fluid power systems. Both the male and female halves of the connections have 37° seats. The seal takes place by establishing a line contact between the male flare and the female cone seat. The threads hold the connection mechanically.

CAUTION: In the -02, -03, -04, -05, -08 and -10 sizes, the threads of the SAE 45° flare and the SAE 37° flare are the same. However, the sealing surface angles are not the same.

Inch Size	Dash Size	Nominal Thread Size	Male O.D. (Inch) Fraction	Male O.D. (Inch) Decimal	Female I.D. (Inch) Fraction	Female I.D. (Inch) Decimal
1/8	02	5/16-24	5/16	.31	9/32	.27
3/16	03	3/8-24	3/8	.38	11/32	.34
1/4	04	7/16-20	7/16	.44	13/32	.39
5/16	05	1/2-20	1/2	.50	15/32	.45
3/8	06	9/16-18	9/16	.56	17/32	.51
1/2	08	3/4-16	3/4	.75	11/16	.69
5/8	10	7/8-14	7/8	.88	13/16	.81
3/4	12	1 1/16-12	1 1/16	1.06	1	.98
1	16	1 5/16-12	1 5/16	1.31	1 1/4	1.23
1 1/4	20	1 5/8-12	1 5/8	1.63	1 9/16	1.54
1 1/2	24	1 7/8-12	1 7/8	1.88	1 13/16	1.79
2	32	2 1/2-12	2 1/2	2.50	2 7/16	2.42

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